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A MANUFACTURING METHODS AND TECHNOLOGY STUDY COVERING
APPLICATION OF AUTO. (U) MARTIN MARIETTA AEROSPACE
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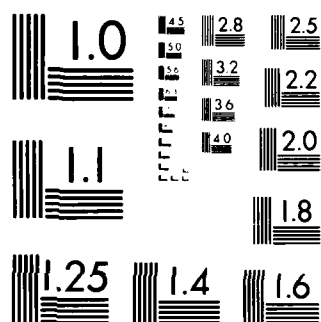
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A MANUFACTURING METHODS AND TECHNOLOGY STUDY
COVERING APPLICATION OF AUTOMATED MANUFACTURING
PROCESS TO METHODS FOR AFFIXING ELECTRICAL
CONNECTORS TO CABLES

OR 13,345-4

September 1975

FINAL REPORT (2 VOLUMES)

Volume 1

By

Frederick E. Tartaglia

Task Leader

APR 3 1985

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U.S. ARMY MISSILE COMMAND

Redstone Arsenal, Alabama 35809

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MARTIN MARIETTA AEROSPACE
Orlando Division
P.O. Box 5837
Orlando, Florida 32805

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A MANUFACTURING METHODS AND TECHNOLOGY STUDY COVERING
APPLICATION OF AUTOMATED MANUFACTURING PROCESS TO THE
METHODS FOR AFFIXING ELECTRICAL CONNECTORS TO CABLES

Final Report (2 Volumes)

Volume 1

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By

Frederick E. Tartaglia
Task Leader

For

U. S. Army Missile Command
Redstone Arsenal
Richard A. Kotler, Program Director

Contract No. DAAH01-74-C-0977

Martin Marietta Aerospace
Orlando, Florida

FOREWORD

Martin Marietta Aerospace, Orlando, Florida, submits this final report in compliance with MICOM Basic Contract DAAH01-74-C-0977 and Modification P00002, entitled, "Application of Automated Manufacturing Process to Methods for Affixing Electrical Connectors to Cables". The program, consisting of a three-phase, 12-month basic program with a two-month extension, was completed on schedule at the end of August 1975.

The program covered:

- 1 The survey and study of harnesses and cables used in current missile systems, and the equipment available to process these harnesses.
- 2 The evaluation of the component parts of these harnesses and cables (connectors, wires, ties, etc.), and the study of specifications and restrictions that control the fabrication of these parts.
- 3 The development of a conceptual design for a mechanized facility for fabrication of harnesses and cables, using manual interfaces for those operations that cannot be mechanized practically or economically.
- 4 The further study, during the two-month extension, of;
 - a The presizing of the wires
 - b Western Electric custom assembly machinery for usable design principles.
 - c The more complex stripping methods that might be applied
 - d The application of soldering of crimp contacts in the conceptual facility design.

A series of charts and data displays has been developed and documented in this final report to show component characteristics and equipment capability, directions for simplification and standardization, and process problems and solutions. These studies identify a logical direction of effort for the conceptual design and the developments needed for

implementation of a prototype facility that could demonstrate the principles proposed in the report.

Included in this report, as Volume 2, is a manual entitled, "The Conceptual Design of an Automated Prototype Wire/Connector Interconnection Facility". This manual will include data on the equipment required, specifications, new designs required, control system, flow diagrams, etc., necessary to describe the proposed conceptual facility.

A carry-on effort for 25 months will follow this basic contractual effort.

ACKNOWLEDGEMENTS

Acknowledgement is given to the many technical people within Martin Marietta and in industry whose participation through conferences and surveys has contributed significantly to the success of this program.

Contributions by Martin Marietta personnel are also acknowledged: Messrs. Earl F. Lish, Herbert L. Sullivan, James W. Denison for their important participation as members of the program task team in the development of program parameters and system concepts; Messrs. J. W. Stevenson and J. D. Keller for overall program guidance.

Acknowledgement is also given to Mr. Richard A. Kotler, AMICOM technical representative, for his assistance and technical contributions to the program and in the preparation of this document.

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1.0 INTRODUCTION

1.1 Statement of the Problem

The objective of this program was to develop new automated techniques for the attachment of Military cable to Military connectors.

APPROACH TO THE PROBLEM

The solution to the basic problem of developing automated techniques for attachment of cables to connectors required a significant amount of preliminary effort in order to establish the parameters that controlled the actual development and design effort.

The first requirement was a survey phase in order to determine:

- 1 The characteristics of the currently required harness components used in MICOM missile systems (wire, connectors, ties, etc.) and effects of these characteristics on automated fabrication.
- 2 The different means of terminating wires into connectors.
- 3 What specifications controlled the processes.
- 4 What equipment was currently available to perform preparation and assembly operations.

At this time an evaluation and selection phase was necessary to select high usage components that were compatible with mechanized fabrication. These parts were used as a basis for a standardization proposal, which was the nucleus around which the mechanization concept was developed.

As this concept developed, key operations required conceptual hardware to prove out basic feasibility and to give credibility to the whole concept. Any necessary manual interface operations were listed and described, and the overall concept completely documented with equipment, control systems, in-process testing, flow plans, schematics, facility layouts and specifications.

2.0 BACKGROUND

2.1 Current Manufacturing Capability

Equipment presently available can automatically perform some of the operations required for the mechanized assembly of cables, harnesses, and connectors.

An analysis of the processes required to assemble cables and harnesses, and a survey of the equipment presently available, showed that a small portion of these process requirements could be performed by automatic equipment. Machinery is available that would automatically measure, mark, strip, and terminate wires. Other equipment can lay wire in an N/C configuration on a tooling board. Testing of harness systems is already a reality. However, there were many procedures that have never advanced from the manual mode. These operations were restricted to manual processing because of the lack of uniformity of the components that could be specified. These components have proliferated at an overwhelming rate with no attempt at control for automation. Each change in requirements, no matter how small, was used to justify a new connector or contact configuration, with little or no attempt to establish a standardized set of basic interchangeable components.

The processing area most affected by this condition was the wire/connector interface. Here, the manual procedures have never been replaced by mechanized operations because of the wide variety of processes required to handle the different configurations.

It is to this area that the program study has directed the greatest emphasis. The solution of the handling and processing problems at this point was required in order to open the way for a complete system concept that was feasible and compatible with mechanization.

After the conceptual approach for this area of processing had been established, the conceptual designs for new equipment were developed to handle the fabrication requirements. At this point, the conceptual system development was expanded to take in the other necessary functions such as wire laying, in-process testing, control, tying, etc. Designs for this equipment were then developed, and a total concept proposed with conceptual machine designs that demonstrated the key operations of the whole fabrication facility.

Certain operations beyond the scope of the present effort will remain as manual processes and will be incorporated into the overall concept as such, so that minimum loss to the system capability will be incurred.

3.0 SUMMARY

3.1 All Program Obligations Have Been Fulfilled on Schedule.

In 1974, the Army Missile Command (MICOM) initiated a study program entitled, "Application of Automated Manufacturing Process to Methods for Affixing Electrical Connectors to Cables". This program studied one of the "cost drivers" in missile system manufacture and attempted to develop approaches that would ^ucounteract the high costs of certain key operations necessary to the production of current and future Army missile systems.

This program made a study of current missile system harnesses and the available means of manufacturing these harnesses. In addition, a study was made of the specifications and restrictions under which these harnesses were manufactured, and a proposal was made on the most practical method for simplification and standardization of these manufacturing procedures.

The specific objectives of this program were:

- 1 Investigate the effects of cable construction on automatic cable/connector fabrication.
- 2 Investigate various methods of connecting contacts to connectors automatically.
- 3 Investigate present MICOM missile system fabrication requirements to establish weaknesses and/or additional requirements needed to permit automatic fabrication.
- 4 Study and determine the types of connectors best suited for a mechanized assembly concept.
- 5 Select ten to fifteen sample MICOM harnesses to be used for future hardware development of the chosen concept.
- 6 Investigate and document methods for automatically stripping insulation and moving the sheath back to allow room for connections.
- 7 Develop and document a concept of prototype apparatus for automatically affixing electrical connectors to cables.

Results

Evaluation of the survey data has resulted in charts and reference lists that give a comprehensive picture of the equipment, components, specifications, adaptabilities and mechanization requirements associated with present day missile harness fabrication. These charts, listed below, are shown and described in the facility design manual, Volume 2, of this final report:

- Military Standard Harness Electrical Connectors
 - Connector Intermateability
 - Contact Intermateability
 - Interconnection and Process Problems Relating to Automated Fabrication
- Standard Automatic Wire Processing Equipment
- Special Automatic Wire Processing Equipment
- Mechanized Operations
- Manual Operations
- Concept Feasibility Study Units

This data identified the MIL-specifications within which the program was operating, the compatible connectors and contacts that were valid candidates for this program, the equipment and processes available, and the areas of manual interface where the greatest amount of attention and effort was required.

It was important that a solder termination capability be a part of the conceptual facility for those programs that preferred or required that capability. Since no insertable solder type contacts were available in the high-usage wire sizes (20, 22, and 24 gage), a study was made on the soldering of crimp type contacts, as purchased, to fulfill this function (see Appendix I). Six methods were investigated with conceptual shop hardware, and a resistance type process was selected as part of the conceptual facility design and was incorporated into the design manual, Volume 2, of this final report.

The survey showed that the industry trend was predominantly toward the environmental connector with removable contacts. This family of connectors could use both crimp and solder contacts and was covered by either MIL-specifications or MIS-documentation. These connectors were also compatible with a mechanized concept and therefore were selected as the basis for the first shop feasibility studies.

As a result of the above data, the primary program direction was determined and shop feasibility studies were directed toward, and concentrated on:

4.0 TECHNICAL APPROACH

4.3 Phase II - Evaluation and Selection (References 2 and 3)

Materials and processes determine concept parameters.

Scope

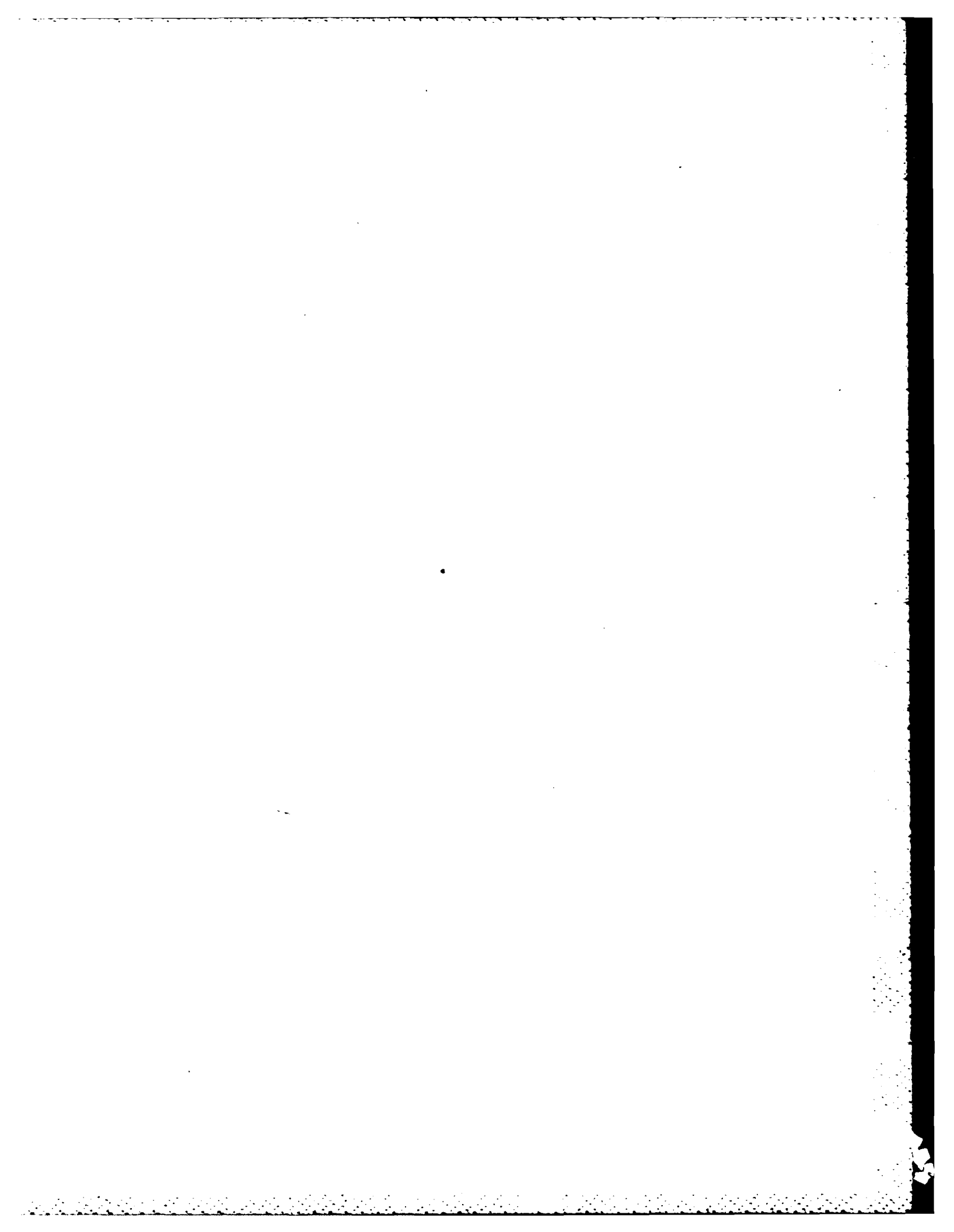
Analysis of the data gathered in Phase I of the program has resulted in a listing of the materials and processes that would be compatible with a mechanized harness concept. The processes required to prepare wires and fabricate a harness were listed and broken down into mechanized and manual operations. An overall in-depth study of these operations resulted in a basic conceptual approach to mechanized harness fabrication that appeared to be feasible and practical.

This concept proposed the pre-sizing and termination of wires by either crimp or solder, and the storage of these wires in a specified sequence on a reel. The reel would then be loaded onto a dispensing machine that would place the wires in a specified harness configuration and insert the ends into connector cavities as designated in a harness running list and programmed into the control system.

The proposed concept contained process operations that were not a part of the present manual process, and it was therefore necessary to develop conceptual designs for a number of new pieces of equipment to fulfill these new process requirements.

All of the operations required to fabricate harnesses by this new concept were listed, and a sublist broken out, of the processes that could be performed by existing equipment. The balance of the operations were analyzed and conceptual designs developed for those processes that appeared to be most compatible to mechanization. The remaining processes were listed as "Manual Interface Operations" and divided into three categories or priorities of importance.

From the above list, a "Concept Feasibility Study List" was prepared and conceptual hardware designed and fabricated in order to demonstrate feasibility of the basic conceptual approach to the fabrication facility.



Another result of the survey was data showing how standardization could be achieved by use of interchangeable and compatible connectors and wires. These components were listed across companies and manufactured to standard dimensions.

Conclusions and Recommendations

The environmental connector with the resilient rear face and the "cork and bottle" interface can be used for most of the current harness connector requirements.

Wires can be prepared and terminated automatically on a programmed basis.

It was recommended that the following operations be considered as manual in the initial concept development:

- 1 Wire preparation of tough exotic insulations.
- 2 Wire preparation of shielded twisted pairs.
- 3 Wire preparation of multiple shield terminations.

It was further recommended that the facility concept approach be in the form of multiple coordinated machine components, and not in one complex total process machine.

PARAMETER	MANUFACTURER/USER RESPONSE
CONNECTORS	Military usage tends toward removable crimp contacts and away from non-removable solder contacts. Unable to locate a circular wire wrap connector; rectangular connectors located are commercial and not environment resistant.
WIRE	20-24 gage is popular for military usage. Considerable stranded, shielded, single conductor and twisted pair is used for flight hardware, while solid is used for wire wrap terminations on back panels of ground support, data processing equipment.
INSULATION	Kapton has excellent service properties, but is more expensive and harder to prep than Kynar, polyalkane, Teflon, Tef-Zel, Mylar or polyarylene.
SHIELDING	Braided is better RF shield than spiral, is easier to terminate on coaxial cable but harder to terminate on twisted pair; spiral shielding is easier to process manually.
MIL-SPECS	Of the 10 wire manufacturers contacted, 10 said MIL Spec wire costs more, 4 said there are too many specs, 2 said the quality was higher than commercial, and 1 said some commercial specs were tougher.
COMMERCIAL PROCESSES OR HARDWARE	Flat cable plus insulation displacement connectors are becoming very popular for commercial data processing and communication equipment, in addition to wire wrap.
PREP EQUIPMENT	Some usage of semiautomatic and automatic machines to measure, mark and cut wire, plus hand or semi-automatic crimp terminations. WE-Burlington has surplus SAFEGUARD automatic stripper/terminator for coaxial cable. Grumman has a CONRAC/AMP machine to automatically measure, mark, cut, strip and terminate one wire size at a time.
HARNESS FABRICATION	Mostly a manual operation throughout industry due to lack of equipment, high cost of the equipment that is available, and the unattractive economics of low volume/large variety harness production. WE-Dallas has a machine to lay single conductor or twisted pair for wire wrap harnesses. Fairchild has a machine to N/C locate, lay and manually insert both ends of terminated wires into connectors.

FIGURE 4. PRELIMINARY SURVEY RESPONSE.

METHOD	PRESENT APPLICATIONS/AVAILABILITY (11 CONNECTOR MFTRS CONTACTED)
SOLDER	<p>Six manufacturer's list MIL Spec solder type connectors, all with non-removable contacts. This type connector is not considered compatible with automatic harness fabrication concepts.</p> <p>Raychem is only source of solderable removable contacts interchangeable with crimp type. Pyle-National claims its crimp type contacts can be modified so as to be crimped or soldered.</p>
CRIMP	<p>Eight manufacturer's make MIL Spec crimp contact, rear entry connectors. Raychem makes solderable, removable contacts for these connectors(see above). These connectors and contacts are considered compatible with automatic harness fabrication concepts.</p>
WIRE WRAP	<p>Five manufacturers make wire wrap connectors, none usable for MIL Spec Harness connectors. Therefore, this type connection is not considered applicable to automatic harness fabrication concepts. Main usage is for backpanel wiring of military and commercial ground support data processing equipment.</p>
INSULATION DISPLACEMENT	<p>Four manufacturers make insulation displacement connectors that pierce the wire insulation to make electrical contact with up to 50 wires simultaneously using flat cable. Used primarily for commercial computer, communication and automotive wiring. Since these connectors are not MIL Spec, they will not be considered further.</p>
WELD	<p>Unable to locate MIL Spec or commercial harness connector designed for welding therefore this method will not be considered further.</p>

FIGURE 3. CONTACT CONNECTING METHODS.

EFFECT OF CONNECTOR CONSTRUCTION PARAMETERS ON ADAPTABILITY TO AUTOMATIC HARNESS FABRICATION										
COMPANY	CONNECTOR CHARACTERISTICS			CONTACT CHARACTERISTICS		SPECS		FOR AUTO. ASSY.		REMARKS
	REMOVABLE CONTACTS	NON-REMOVABLE CONTACTS	CONTACT METHOD	INTERCHANGEABLE IN SAME CONNECTOR	CONTACT TENSILE FOR AUTO. ASSEMBLY	SUGGESTED CONN. PROCESS/EQUIP.	MIL SPEC RESTRICTIONS			
AMP	YES	NO	CRIMP	N/A	MIL	NO				Mostly commercial mfg.; Makes an insulation displacement connector; makes Rect. Conn per MIL-C-81659
AMPHENOL	YES	YES	WIRE WRAP	N/A	COMMERCIAL	YES		--		Mostly commercial. Circulars to 5013, 26-25, 26500, 38000, 81511, 83723, MAS 1599.
ANSLEY	NO	YES	CRIMP	N/A	MIL	NO		Costly to meet		Rectangulars to 26518, 14300
BENDIX	YES	YES	SOLDER	N/A	COMMERCIAL	YES		Not Used		Insulation displacement process crimps 50 conductor flat cable into connector all at one time.
BERG	NO	YES	WIRE WRAP	N/A	COMMERCIAL	YES		Cost high due to Quality requirements		Makes: 0026482, 83723, 38999, 27599, 345
DEUTSCH	YES	YES	CRIMP	N/A	MIL	NO		Not Used		Mentioned AF problem with -83723
HUGHES	YES	YES	SOLDER	N/A	COMMERCIAL	YES		Too many Specs. Limited Interchangeability		Insulation displacement process crimps 50 conductor flat cable into connector all at one time.
ITT-CANNON	YES	YES	CRIMP	N/A	MIL	NO		--		Makes: 0026482, 0081511, 81703, 83723
MARTIN MARIETTA	YES	YES	SOLDER	N/A	COMMERCIAL	NO				Circular commercial connectors. Rectangular connectors to MIL-C-28748.
PIE	YES	YES	CRIMP	YES	MIL	NO		MIL Connectors not practical for Auto. Assy.		Makes: 005015, 25482, 26500, 38999, 83723, 83733 + 1025299 for SAM-D. 005015 contacts are #12 Coaxial, Solder/Crimp.
PRYLE-NATIONAL	YES	YES	SOLDER	YES	COMMERCIAL	YES		N/A		User, not mfr.; special 1025299 and 11176709 developed for SAM-D and Sprint.
RAYCHEM	YES*	YES	CRIMP	N/A	COMMERCIAL	YES		Not Used		Uses Raychem removable, solderable, contacts. Primarily computer business + some ground control equipment.
TRW-CLINCH	YES	YES	SOLDER	N/A	COMMERCIAL	NO		Cost high due to Quality requirements.		Makes special Sprint Connector 11176709. Says crimp contacts can be made solderable.
			CRIMP	N/A	COMMERCIAL	YES		Too many Specs.		Sole source of removable solder contacts for SAFEGUARD and SAM-D. *Contact only.
			SOLDER	N/A	COMMERCIAL	NO		Too many Specs. Interchangeability problems		Mostly commercial. Makes 26500, 38300, 81511. Mentioned AF problem with 81511

FIGURE 2. CONNECTOR SURVEY RESULTS.

EFFECT OF WIRE CONSTRUCTION PARAMETERS ON ADAPTABILITY TO AUTOMATIC WIRE HARNESS FABRICATION				
COMPANY	STRANDING, LAY, INSULATION, SHEATH	SHIELDING	MIL SPEC RESTRICTIONS	REMARKS
COMMERCIAL USERS				
Stromberg Carlson	Wire wrap equipment used on commercial communication equipment.			
General Electric	Hand laid harness assemblies for Terminate data transmission.			Hand stripping and hand soldering
TBW-Holyoke	A commercial wiring harness job shop used by Scott Electronics		Not used.	No work with Kapton. No indication of equipment used. Mentioned AMP's work on a new terminator.
United Airlines	Uses hand laid wiring harnesses. Automatic equipment not cost effective due to limited volume plus wide variety. Evaluating TEF-ZEL, Kapton and polyethylene insulations.			Have tried AMP type of automatic contact crimpers.
Western Electric	Has three custom built automatic wire laying machines capable of laying any of a number of single or twisted pair wire sizes. No stripping, no termination. Hand tied. Used for SS-1 harnesses on commercial telephone equipment.			Unable to visit due to patents pending. WECO articles due for publication late 1974 - early 1975.
EQUIPMENT MANUFACTURERS				
Arcon	No machine for stripping twisted pair or for any jacket over spiral shield.			
CONRAD	Makes only one machine: WDM-501 which measures, marks, cuts, and strips single conductor (single gage at a time) wire to any length and with any marking inputted to the tape control.			No interest in automatic harness concept.
Eubanks	No machine for stripping twisted pair or for any jacket over spiral shield.			
Raychem	Makes semi-automatic coaxial cable stripper/terminator using Raychem's Soldertact rear entry, front release contact.			Also makes Powertact rear entry, front release soldered contacts conductor.
Region	Makes Reem brand of novel, manual stripper for twisted pair, including Kapton over spiral shield.			Could become part of concept.
CONNECTOR MANUFACTURER				
Pyle National				Attempted an automatic harness machine for Military Air Transport Service.

FIGURE 1. WIRE SURVEY RESULTS (Continued).

WIRE CONSTRUCTION PARAMETERS IN ADAPTABILITY TO AUTOMATIC WIRE HARNESS FABRICATION				
NAME	STRANDING, LAY, INSULATION, SHEATH	SHIELDING	MIL SPEC RESTRICTIONS	REMARKS
<u>WIRE MANUFACTURERS</u> Belden	Stranding and lay determined by manufacturers prior to MIL spec inclusion. Fine strands increase flexibility, tight lay decreases. PVC/nylon easy to strip.	Braid stronger. Spiral easier to pigtail.	Too many specs. Some commercial are tighter.	Primarily commercial. No Kapton, Kynar or TEF-ZEL.
Brand Rex	Stranded for easier harness laying. Polyethylene insulation preferred. Kapton worst to strip.	Braid more expensive and harder to strip.	Make wire more costly. Quality is improved.	Flat conductor cable better adapted to automatic fabrication. Avoid Kapton's cost, stiffness and stripping problems.
Chas.	Stranded more fatigue resistant than solid wire. Kapton has excellent properties but expensive and hard to prep. Teflon is easy to strip.	Prefers braid for MIL usage, and metallized Mylar + drain wire for commercial.	Too many. W-16878 is adequate in most cases. NAS-702/-703 not necessary. Foil shield not allowed.	Primarily a fluorocarbon supplier, not Kapton.
Cole	Stranded wire is flexible. Lay rule-of-thumb: Turns/inch = inches O.D. of wire bundle x 12. Extruded Teflon harder to strip than tape-wrapped Teflon. Kapton is hardest to strip.	Braid adds mech. strength, is better RF shield than spiral and is easier to terminate with ferrule.	Not used. Increases cost but not always quality.	No interest in TEF-ZEL. Primarily make 105% Mylar wrapped wire for commercial computers. Uses special Ideal Company stripper blades (similar to Martin's).
Hudson	A primary wire producer only - draws wire: bare, silver or nickel coated. No insulations.	N/A		MIL Spec's for bare wire are based upon ASTM Spec.
ITE Sorenson	Make stranded hookup wire to MIL-W-16878 plus non-spec stranded with heavier tin coating to permit heat tack of strands prior to strip.	N/A	Heavier tin coating too stiff per MIL Spec.	Primarily a cable supplier to military for ground support equipment.
Prestolite	Stranding provides flexibility and fatigue resistance. Lay determined through years of trial/error. Fine stranded wire to ASTM-B33 (40 microinch) by hot tin dip; heavier coatings (to 150 microinch) for heat tack prior to strip requires electrotin. Kynar liked, but tightness of Kapton disturbs lay during strip.	Braid easier to make but takes more wire than spiral.	Makes cost higher but wire is not necessarily better. Many wires are over-spec'd.	Electroton wire made by London Wire. Neither Kynar nor Kapton can be applied over tin since their process temperatures are above tin's melt point.
Ravhen	No. of strands change from 7 for 26 Ga. and up, to 19 for 24 Ga. and down. Heat tack prior to strip bonds only outer strands together. Kynar liked. Kapton hard to strip.	Prefers braid. Metallized Mylar + drain wire is good but makes wire out of round and hard to strip.	MIL-W-16878 is easy to meet (non-OPL). W-8104 is OPL and is higher quality. Disallowance of foil shield.	Prefers non-fluoro brand of polyethylene to Kapton. Dupont's TEF-ZEL (tetrafluoroethylene) said to be better than Teflon or Japanese equivalent of TEF.
Teledyne	Buys plated wire, then strands and insulates. Wire lay follows MTR design of yesteryear - still good today. TEF-ZEL rated high. Kapton and Kynar are hard to strip.	Braid strengthens wire. Spiral may have broken ends that could lead to shorts in an extruded jacket. Likes foil + drain wire.	Assures quality wire. Disallowance of foil shield. Increases cost.	Supplies TEF-ZEL insulated wire to Northrup. Company is big in TFE extrusion. One of three Kapton suppliers on Space Shuttle.
Tensolite	Stranded is more flexible and more expensive. Primarily a user of Teflon and Kapton. Kapton is hard to strip.	Braid is more efficient than spiral.	Wire is more expensive due to test cost.	Big supplier of Kapton to Lockheed for F15. Likes TEF-ZEL.
<u>WIRE PROCESSORS</u> Eubanks	Mostly military work using wire wrap equipment for data processing equipment.			Do not know used except wire wrap and Eubanks stripper.
Estimote	Made semiautomatic point-to-point wiring and contact insertion machine. Uses reels of pre-terminated (MIL Spec crimped contact wires). Contacts are positioned over correct connector hole by No. dispensing head, and inserted manually by a pull on a handle. Machine then travels to next connector position for insertion of contact on other end of wire.			Machine does 4000 wires a minute. Fully automatic. 100 contacts each on one machine for military data processing equipment.
Harwin	Have new-of-a-kind Harwin AMP machine to measure, mark, cut, strip and automatically crimp MIL Spec contacts onto 26 Ga. stranded wire for MIL-C-81511 connectors.			Prep. wires used on F15, A7, and EA military aircraft. Likes Kapton, and it is OK.
James	No automatic wire processing equipment except Eubanks stripper and wire wrap equipment.			Used in military data processing equipment.
<u>MILITARY USERS</u> Martin Marietta	Mostly defense work. Automatic wire processing equipment includes no wire wrap and Eubanks stripper.	Uses considerable Kapton insulated, spiral shielded. Kapton sheath, twisted pair 20 and 24 Ga. wire.		Twisted pair is most difficult to prep, especially if shielded by spiral wrap, and most expensive if Kapton sheath and Kapton primary insulation are used.
Levy	Mostly military work using wire wrap equipment on data processing equipment.			No automatic machine used in harness assembly except Eubanks.
Rockwell Systems	Has new-of-a-kind automatic coaxial cable stripper and termination machine designed to use Ravhen's heat removable, front release solderable coaxial connector contact. Also has new-of-a-kind semi-automatic twisted pair termination machine designed to use Ravhen's similar solderable contact for twisted pair.	Braid is blown back over coaxial sheath just prior to termination.		Machines are surplus SAFARI equipment. Papers are in use to transfer equipment to Martin Marietta. No use in this MIL-Harness project.

FIGURE 1. WIRE SURVEY RESULTS.

4.0 TECHNICAL APPROACH

4.2 Phase I - Survey (References 1 and 2)

Aerospace and commercial manufacturers were surveyed to ascertain current harness requirements.

Scope

An industry survey was conducted by way of questionnaires, telephone conferences, and visits to aerospace and commercial manufacturers to record data pertinent to the current industry harness environment. Effects of manufacturing characteristics of wires and connectors on mechanization are shown in Figures 1 and 2. Methods of connecting contacts to conductors are shown in Figure 3. A portion of the survey also sought out sources of equipment that could perform any of the required processes.

Fifty-seven survey participants were selected from a list of hundreds of candidate companies. The survey response is shown in Figure 4. In general, findings show that equipment capability, industry-wide, is extremely limited and in very low usage because of equipment costs and the unattractive economics of low volume - large variety harness requirements.

A list of the military specifications affecting the harness operations was also developed at this time, along with any additions or changes that would be necessary to make them compatible with mechanized harness fabrication.

Results

The survey has resulted in location of a few pieces of equipment that will partially process wires for use in harnesses. Equipment can be purchased that will measure, mark, cut, strip and terminate wires.

The survey also showed that certain insulations, such as Kapton, are extremely difficult to process. Also, certain configurations, such as twisted pairs or shielded wire are difficult. Applying a ground wire to a shield is another tedious complicated operation.

One major fact that has become evident in the survey was the large and increasing use of the environmental connector with rear entry, rear release contacts.

manual interface operations that were beyond the scope of the present effort. In-process testing and system control was described, and conceptual hardware was fabricated to demonstrate feasibility in key operations of the fundamental concept.

Program Extension

The two-month program extension provided time to study four overscope problems:

- 1 Fabrication of a standard compatible harness using the new concept of presizing and terminating the wires before assembly.
- 2 Study of the SAFEGUARD equipment for design features that may be usable on the program concept.
- 3 Further study on methods of stripping difficult insulations and braiding.
- 4 Further study on soldering of terminals.

4.0 TECHNICAL APPROACH

4.1 General

All program tasks and milestones have been completed on schedule.

All program tasks listed on the basic program plan, the two-month extension, and all milestones have been completed on schedule and documented according to contract requirements.

The 12-month program consisted of the following three basic areas of study, with an additional two-month extension awarded to study factors brought out in the basic study.

Phase I - Survey

Phase I consisted of an industry survey to aerospace and commercial companies in order to determine and document prerequisite information on the current industry harness environment.

During this phase, information was gathered on component characteristics, specification requirements, processing methods, and equipment availability. Possibilities were studied for standardization and interchangeability of components across companies, and MIL-specifications were studied and those selected that would control during the concept development phase.

Phase II - Evaluation and Selection

This phase consisted of the evaluation of the information gathered in the survey in order to determine the materials and processes best suited to mechanized fabrication. This data then formed the basis for the selection of fundamental concepts and techniques that could be used for the mechanized processing of wires, contacts, and connectors into a harness configuration.

Phase III - Conceptual Design

The third phase concentrated on the conceptual design of a prototype fabrication facility for preparation of the required wire elements and the processing of them into a harness configuration. This facility listed the currently available equipment, the new designs required, and the

the presizing and termination of the harness wires in a sequenced order, storage in sequence in a staging area, and the subsequent dispensing of the wires in a harness configuration.

Further development of this basic approach has resulted in conceptual hardware that has proved out the feasibility of key points of the concept.

Block flow diagrams were prepared and the mechanized and manual operations defined. Floor plans and equipment needs were established. In-process testing was incorporated in the process flow and a concept design proposed for a prototype machine.

A two-month extension to the program gave time to check out the presized wire idea on a sample harness and to study custom SAFEGUARD terminating equipment for usable design features. More exotic means of stripping were also studied, as was the solder termination problem.

This program has resulted in a recommendation to fabricate a simplified engineering prototype facility to demonstrate system feasibility and to make experimental runs.

With the delivery of this final report and design manual, all contractual documentation requirements will have been fulfilled. The documentation consisted of monthly status reports, formal quarterly reports (approximately 250 pages), and the final report and design manual. This manual includes data on the equipment required, specifications, new designs required, control systems, flow diagrams, etc., necessary to describe the proposed conceptual facility. Program reviews were also held at major program progress points.

The technical investigation and work was performed in three task phases:

Phase I - Industry Survey

Study the effects of cable construction parameters on automatic cable fabrication. Survey current methods used to connect contacts to conductors to determine adaptability to automatic fabrication assembly. Study MICOM missile system fabrication requirements to determine weaknesses and/or additional requirements needed to permit automatic fabrication.

Phase II - Evaluation and Selection

Study and select connector types best suited for automatic techniques. Select ten to fifteen candidate MICOM cables and connectors for sample hardware. Study of equipment and methods for stripping of insulation and removal of sheathing to allow for connections.

Phase III - Conceptual Design

Develop the conceptual design of an automated fabrication facility for cables and harnesses with emphasis on the termination of wire ends into connectors. Include all documentation including flow diagrams, schematics, sketches, descriptions of manual interfaces, cost analyses, proposed control systems, and proposed test systems.

The survey showed immediately the lack of mechanized fabrication equipment and the prime reason for this condition. The industry has developed an overwhelming variety of connectors, contacts, and processes for constructing harnesses, the major portion of which is not compatible to mechanized assembly.

The survey did show that the environmental type connectors with crimp style contacts are gaining great favor in the missile industry and are being used more and more on the newer missile systems. This type of connector is adaptable to a mechanized concept and has been shown to be equivalent to the older types still in use. The crimp type contact has also been used successfully as purchased, in experimental soldered terminations and can be considered compatible to mechanized fabrication in either the crimp or soldered mode.

A chart was made showing the environmental connectors available and a cross reference showing interchangeability and intermateability across companies.

This type connector was therefore proposed as the preferred type to be used in the proposed mechanized concept developed in this program.

After an in-depth study of the processes that would apply to this type connector, a basic approach was developed. This concept proposed

- 1 Delivery of the terminated wire to the insertion area.
- 2 Capture of the contact by the insertion head.
- 3 Insertion of the contact into the connector.
- 4 Turnover, capture, and insertion of the trailing end of the wire.

Since these items were basic to the concept of mechanized harness assembly, solution of these problems was necessary before attention could be given to the balance of the problems on the priority list.

Another factor that had to be considered was the concept of processing presized wires that have been terminated at both ends. Therefore, an overscope item was proposed for the manual assembly of a harness using presized wires to determine the feasibility of the concept and to identify problem areas and their solutions.

Conclusions and Recommendations

The environmental connector satisfied the requirements of both a crimp type connection and a solder type connection. This environmental type connector appeared to be the logical choice for study in this program because of:

- 1 Its growing popularity and increasing use in the missile industry.
- 2 Its compatibility with the concept of mechanized processing and assembly.
- 3 The intermateability and interchangeability of this type connector across company lines.

The limited industry capability for processing wires indicated the need for a custom wire preparation facility where the different wire sizes and types could be processed with a minimum of basic equipment and a maximum of flexibility through tooling changes.

The MIL-specification study showed that the only significant area not covered in the mechanized concept was the solder sleeve contact. This restriction was shown to be covered by MIS-documentation.

Since the basic shop feasibility studies with conceptual hardware verified the proposed method of approach, it was recommended that the concept be developed around the following basic parameters:

- 1 The concept would use, wherever possible, the environmental connector with separate contacts crimped or soldered to the wires and inserted into the connector body.

- 2 The wires would be precut to length and terminated.
- 3 Difficult or infrequent wires and terminals would be processed manually.
- 4 The prepared wires would be sequenced onto a reel and held in a staging area for scheduling onto the fabrication equipment.
- 5 The mechanized operation of affixing wires to connectors would consist of a pick-up head that would capture the wire end from the reel, insert it into the connector, seat it in its cavity, reverse the trailing end of the wire, and repeat the above described insertion cycle.

It was further recommended that these basic operations be the subject of the first shop feasibility studies.

4.0 TECHNICAL APPROACH

4.4 Phase III - Conceptual Design (References 3 and 4)

Prototype conceptual hardware demonstrates feasibility of proposed facility.

Scope

The shop hardware feasibility studies and the subsequent listing of the fundamental design parameters has established a verified base for the development of the total conceptual facility. This plan was for a total capability in which was defined all of the principal elements of a mechanized fabrication line. This plan included both crimp and solder type termination process lines as well as provision for any necessary manual interface operations. A total control system was incorporated into the concept and also an in-process testing system that could verify the termination strength and check continuity.

Where existing equipment was usable, it was specified and described. Where new equipment was required, a conceptual design was developed and specifications prepared. The parameters for each new machine were developed and preliminary designs made.

Results

The conceptual design of a total capability harness fabrication facility has been defined. It is complete with floor plans, process flow diagrams, cost analyses, preliminary specifications, control systems, test devices, and machine descriptions.

As a result of the conceptual design, the following items are identified and described:

- 1 The preparation and termination of wires with crimp type terminals can be achieved with available equipment.
- 2 The preparation of wires with solder type terminals can be achieved with available equipment, but the solder termination capability will require design and fabrication of new equipment.

3 The following additional equipment will have to be designed and built:

- a The Wire Test and Transfer Machine
- b The Terminated Wire Reeler
- c The Harness Sequence Reeler
- d The Harness Assembly Machine
- e The Harness Tying Machine

4 The Control System will have to be designed and built.

Analyses and cost studies have resulted in cost and time comparisons of the harness fabrication by manual and mechanized processes. Process flow diagrams have been developed that show significant savings when the proper designs are used and optimum mechanization is used (refer to Design Manual, Volume 2, of the Final Report).

Since the implementation of a total-capability manufacturing facility was far beyond the scope of the present program, a simplified facility plan was also developed that could demonstrate the principles of a mechanized operation, but was not intended to fulfill all of the functions of a total production facility. This austere facility would be implemented with full scale experimental machine units that would be able to perform the basic operations proposed in the conceptual facility design. This equipment would be capable of experimental runs for operational demonstration and analysis, or to make procedure studies.

The austere facility would not demonstrate a mechanized soldering capability because of the decision to eliminate the extensive development costs that would be involved. The mechanized solder operation would be described completely and sample parts would be made manually to demonstrate product and process flow through the system.

Conclusions and Recommendations

The cost comparison of the present harness fabrication process to the proposed mechanized concept has shown that mechanization can result in significant savings in time and money. However, this saving can only be accomplished if:

- 1 The harness design follows recommended design procedures that would make it compatible with mechanized processing.
- 2 Production quantities are large enough to justify the capital outlay for the mechanized facility.

It is recommended that the simplified demonstration facility be implemented in order to check out the system concepts with full scale experimental machine modules. This would include design and fabrication of the necessary basic equipment, checkout of proposed operations, fabrication of prototype harnesses, and testing of the harness elements for successful processing. It is recommended that the following pieces of equipment be designed and built:

- 1 Terminated Wire Test and Transfer Machine - This design will include the pick-up of the wire from the wire preparation and termination area, the positioning of the wire, the mechanical and electrical testing of the wire, and the transfer of the wire to the next machine operation.
- 2 Terminated Wire Reeler - This design will cover the pick-up and reeling of the terminated and tested wires.
- 3 Harness Sequence Reeler - The third design will be for a reel-to-reel sequencer. This design is for a machine that will take a variety of reels and transfer the wires into a totally sequenced set of wires on a final harness reel.
- 4 Wire-to-Connector Inserter - The fourth design will be for a wire dispensing and inserting machine that will take the sequenced reel and cycle through the operations required to dispense wire, insert the wire end into a connector, perform a seating test, advance the wire, and repeat the insertion operations on the opposite end of the wire.
- 5 An X-Y Table and Tooling Board - This design will include the X-Y table, the assembly board and the tooling required to hold the connectors and pattern the wires as they are run. Eventually, this machine will work in conjunction with Machine #4.
- 6 A Tying and Test Unit - This design will include the tying of the harness, using commercially available plastic tie pieces, and providing access of a DITMCO type test machine to the system test cables. This unit will be incorporated into the assembly machine (Machines #4 and #5), if possible.

It is further recommended that investigation and implementation be undertaken to complete the other requirements of a prototype demonstration facility with manual interfaces where necessary.

4.0 TECHNICAL APPROACH

4.5 Program Extension

4.5.1 Scope

Fabrication of Sample Harness

One of the concept procedures that required verification was that of presizing wires rather than custom sizing and termination at assembly.

One of the sample harnesses was selected and assembled by the custom sizing method presently in use (Figures 5, 6, and 7). The same harness was then made by presizing and terminating the wires from a running list before assembly (Figures 8, 9, 10, and 11). The harnesses were completed and tied with plastic tie pieces.

Study of SAFEGUARD Equipment

A second task consisted of studying the SAFEGUARD equipment requested from storage at Western Electric in Burlington, North Carolina. This equipment was set up and put into operating condition and a study was made of each of the station mechanisms in order to determine whether any of the designs or principles might be of use in developing the harness conceptual design.

Study of Stripping Methods

Another overscope task was an investigation into the methods of stripping the more difficult insulations and wire braid shielding. Advanced methods of thermal stripping were tried on various insulations and flash stripping was used to separate the braided shielding.

Solder Termination Study

The soldering of crimp type terminals warranted further investigation, and a series of tests were made to improve the wire/terminal interface. Solder quantities were varied and the application methods were changed to determine the optimum conditions and the problem areas.

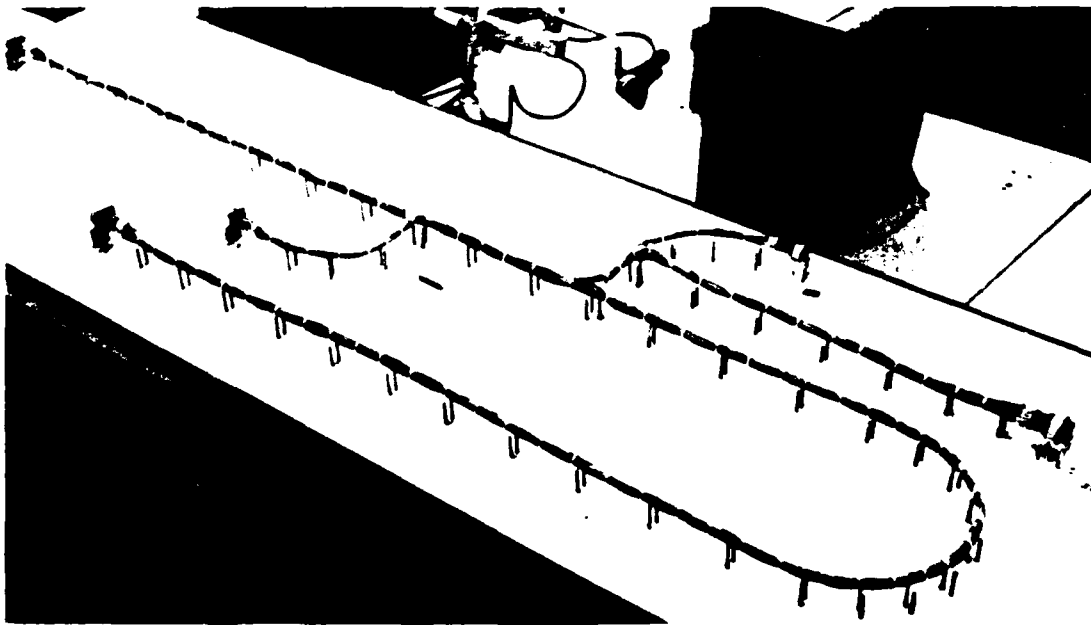


FIGURE 5. SAMPLE HARNESS, CONVENTIONAL

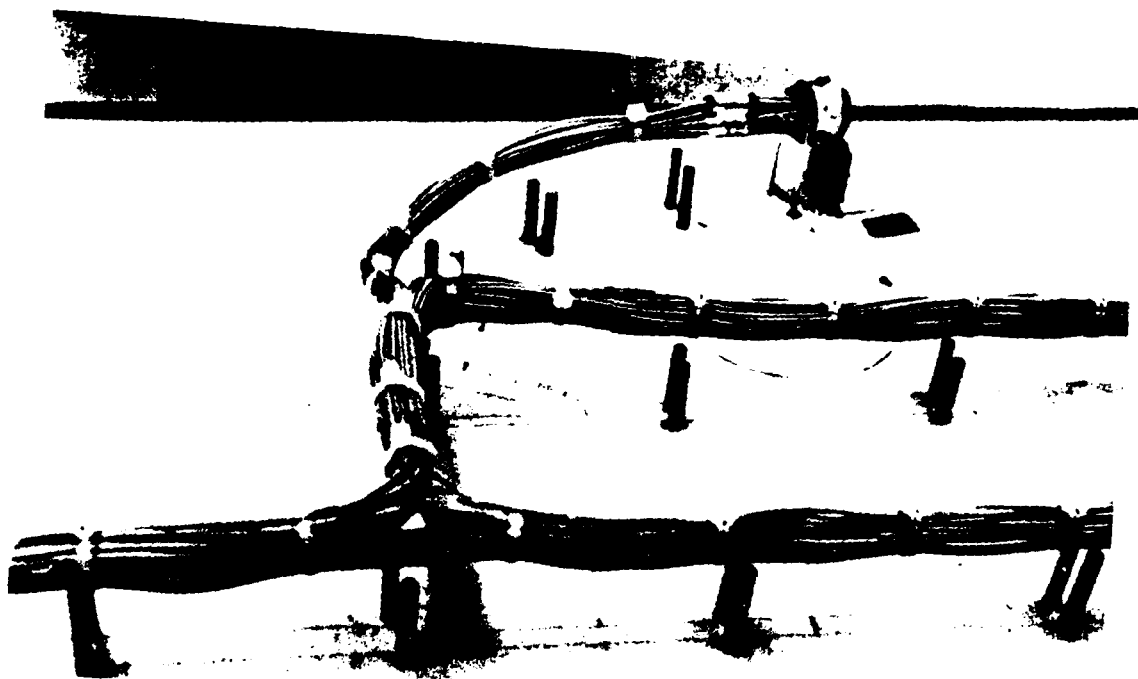


FIGURE 6. SAMPLE HARNESS, CONVENTIONAL

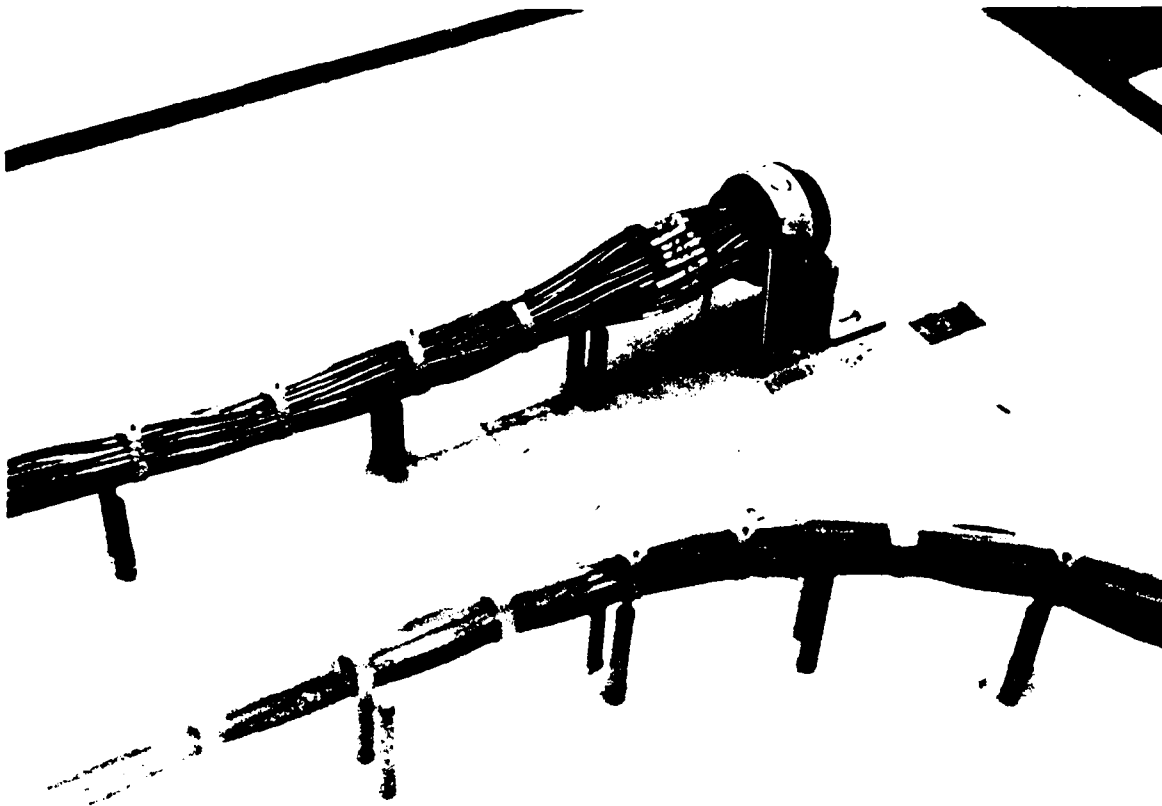


FIGURE 7. SAMPLE HARNESS, CONVENTIONAL

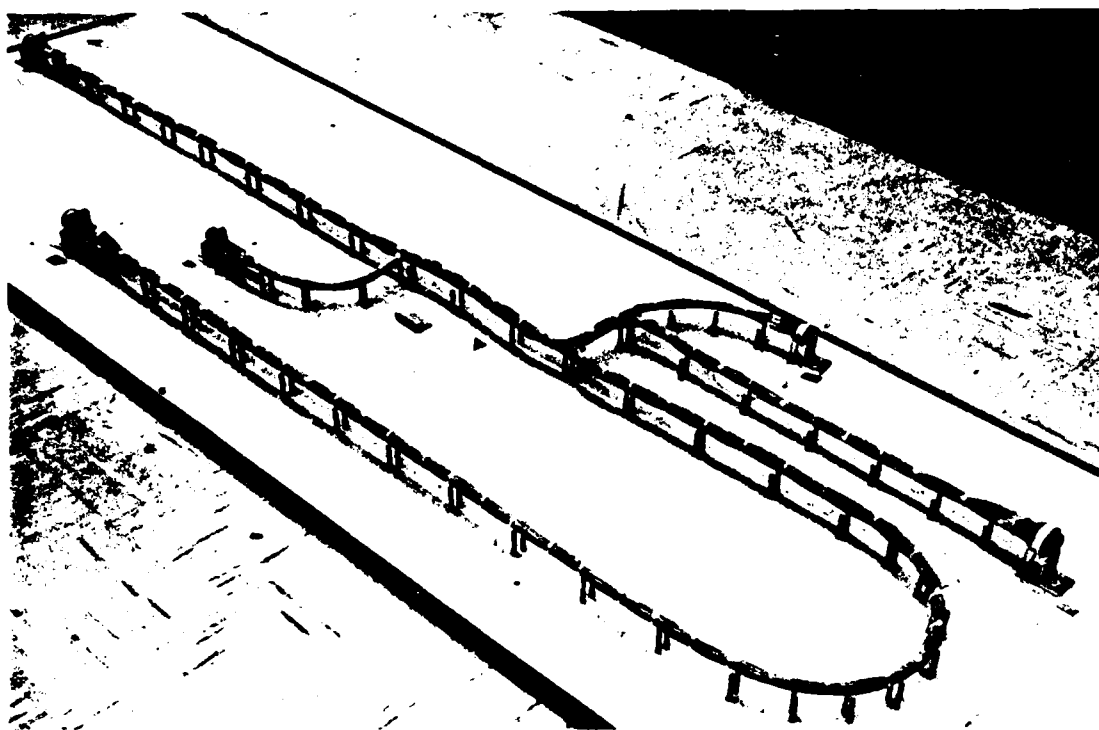


FIGURE 8. SAMPLE HARNESS, NEW CONCEPT

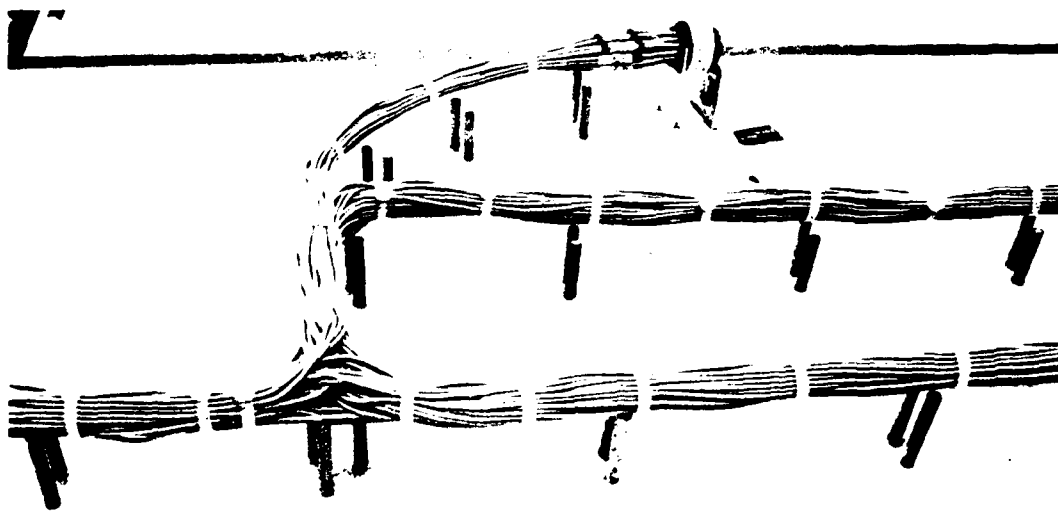


FIGURE 9. SAMPLE HARNESS, NEW CONCEPT

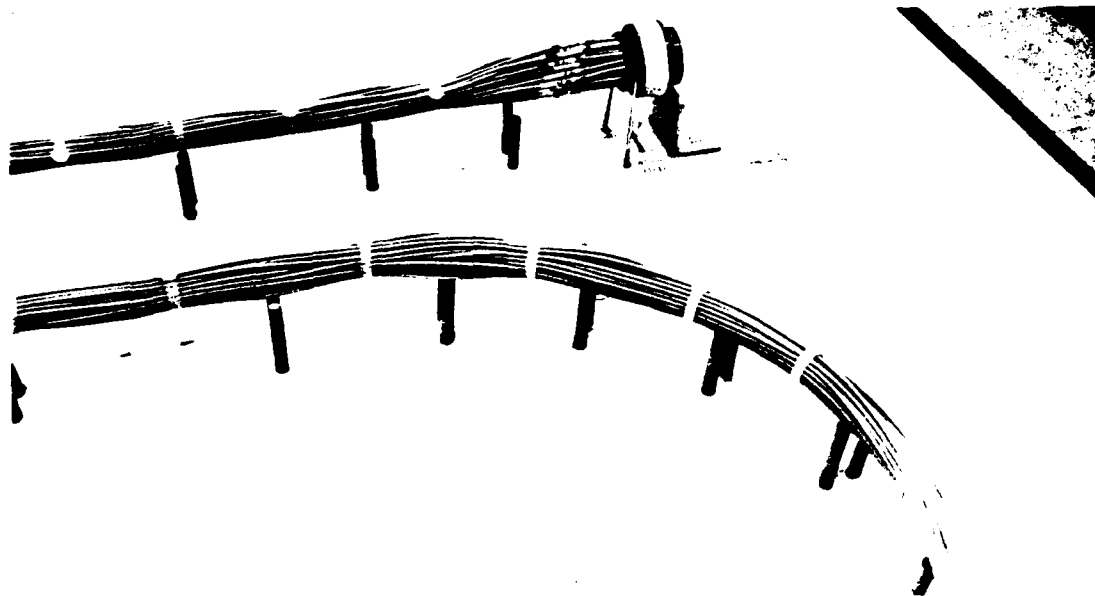


FIGURE 10. SAMPLE HARNESS, NEW CONCEPT

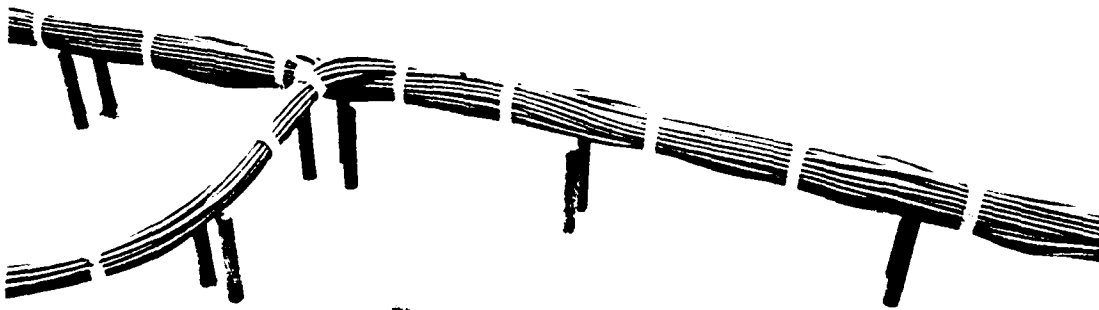


FIGURE 11. SAMPLE HARNESS, NEW CONCEPT

4.0 TECHNICAL APPROACH

4.5 Program Extension

4.5.2 Results

Fabrication of Sample Harness

The harness fabricated with the presized wires was examined by a panel of experienced engineering and manufacturing personnel who had years of background in the design and fabrication of harnesses by the custom sizing method. The members of the panel were unanimous in their acceptance of the harness as equal to or better than the harness made by the old method.

Study of SAFEGUARD Equipment

The study of the SAFEGUARD equipment showed that the principles used were, for the most part, incompatible with the present program concepts. The equipment processed only one end of a wire bundle and each wire end moved laterally through 18 cycle positions from the load to the unload positions. A wire was therefore captured for 108 seconds during its processing time. This principle was not compatible with the conceptual design which used the in-line process to prepare wire ends. However, the capture and test position appeared to have some design features that could be used in the test and transfer section.

Study of Stripping Methods

The thermal stripping of insulations has shown promise in that a satisfactory strip could be made. However, the insulation did show discoloration at the separating surface. The flash stripping of braided shielding was also successful but as in the thermal stripping, showed signs of discoloration on adjacent insulation surfaces (Figure 12).

Solder Termination Study

The solder tests showed up problems that would require attention during the design phase of a solder mechanization program. Solder sometimes flowed over the lip of the terminal or through the inspection hole and interfered with the insertion seal. Heat often discolored the insulation. Wicking sometimes occurred up the wire. The solder fillet, acceptable when the joint was made, receded and became unacceptable when cool.

Conclusions

A. Compatibility With Specifications

- 1.0 All of the solder fillets made per the first five concepts were inconsistent and dull appearing when judged according to the controlling document for manual soldering of electrical connections, MIL-S-45743.

- 1.1 Per para. 3.4.2.1 of Amendment 4 to Revision C of MIL-S-45743: The solder should rise slightly above the top of the cup and form a fillet extending from the conductor to all sides of the solder cup (see Fig. 22).

Furthermore, pretinning of wire conductors is required per para. 3.3.3.5.1 of this same document.

The solder fillets were highly dependent on the amount of solder picked up by the wire during the prior pretinning operation. What appeared via a microscope to be the correct solder fillet, when the solder was molten, subsequently shrank to beneath the solder cup edge when the solder was cool.

- 1.2 The use of sufficient solder to produce an acceptable cool fillet often resulted in solder running onto the outside of the terminal when the solder was molten, contrary to para. 3.4.2.1 which also states: Any excess solder shall be removed (see 3.6.1.2) such that any solder on the outside of the solder cup is in the form of a film only (spot tinning) except terminals with weep holes may have a slight protrusion of solder fillets extending from the hole (see Figure 22).

- 1.3 The dull frosty appearance of the cool solder joint is due to the gold plating inside of the terminal cup and would lead to rejection per para. 4.3.1 which states: The solder connection shall have a smooth, bright appearance, without porosity, cracks, pits and voids which expose bare metal.

- 2.0 All solder connections made per the first five concepts were subject to cleaning to remove flux residue per para. 3.5.1: Cleaning the solder connection. Excess solder shall be removed so that the connection is clean and secure. Mechanical methods such as filing, grinding, or scraping shall not be used. After the solder has completely solidified, all residual flux shall be removed by using a solvent (see 3.1.2). After final cleaning, finished product shall not become contaminated by handling or other means.

- 3.0 The solder fillets made per the sixth and last concept, solder sleeves, cannot be clearly inspected due to the imperfect clarity of the surrounding plastic shrink tubing. For this reason and because flux

Concept No. 6 - The Solder Sleeve Concept

The solder sleeve concept consists of commercially available 1-piece coaxial, twisted pair or single conductor contact assemblies. These units contain carefully engineered preforms of solder and flux within transparent, radiation crosslinked, heat shrinkable tubes preshaped to the precise configuration needed for the application. The prepared wire conductor end is inserted into the desired contact configuration, and the contact assembly is heated under carefully controlled conditions by IR lamps or hot gas guns. The heat acts to simultaneously (1) melt the solder to join the wire conductor(s) to the contact, and (2) to shrink the tube around the wire insulation/contact interface to form both a strain relief and an encapsulant.

Procedure

Three special machines were designed, developed and fabricated by Raychem for Western Electric to automatically affix solder sleeve coaxial contacts to SAFEGUARD ground support cables.

Results

The \$219,303 invested in these three machines resulted in a subsequent SAFEGUARD program savings of \$7,416,956 (ref. SEI ESM B-63-W1-013Z Final Report, Contract DAHC60-68-C-0017).

Compatibility With Mechanized Concept

The WE solder sleeve concept is not compatible with a mechanized concept for the following reasons:

1. The full termination cycle is too long (84 seconds).
2. The process terminates only one end of a wire.
3. The process requires manual load/unload.
4. The termination process is a lateral process instead of in-line.
5. Twisted pair wires must be manually prepared as well as manually loaded/unloaded.
6. Complete retooling will be required to terminate other size contacts, wire and/or cable.

Some principles may however be usable in development in other areas such as the IR lamps used for the IR study in Concept No. 3, the electrical test mechanisms to verify correct wire insertion into contacts, and the insertion mechanisms themselves.

Concept No. 5 - The Resistance Soldering Concept

The resistance soldering concept makes use of a commercially available welding step-down transformer with a high current/low voltage output. This transformer is wired to two metal jaws with appropriate cutouts shaped to grip the contact but not to touch each other. A high current is caused to flow through the jaws and the contact barrel causing the contact to heat sufficiently to melt and flow the solder around the inserted wire conductor. The current is then turned off and the solder is allowed to solidify and cool.

Procedure

This concept was tried as outlined above, using a Carpenter Model 91-C flash stripper set on the lowest power output setting. The metal jaws performed the function of preventing solder leakage through the inspection hole, hence a separate band was not used.

Results

The solder fillets were inconsistent and dull and frosty in appearance for the same reasons as for concepts 1, 2, 3 and 4. The iron jaws prevented solder leakage through the inspection hole; iron was selected since it was not readily wetted by the flux/solder combination used. Aluminum was considered and rejected for fear that purple plague would be formed on the gold plated contact surface.

Compatibility with Mechanized Concept

The resistance soldering concept is the most compatible concept considered for use with a mechanized concept. The main advantages are:

1. Fast (1-2 second heat cycle).
2. Automatic coverage of inspection hole.
3. Flux residue is easily flushed off while contact is still clamped.
4. Easy to control.
5. Inexpensive equipment.
6. Low energy consumption.

There are no serious disadvantages to the resistance soldering concept as a wire-to-contact termination method.

Concept No. 4 - The Radio Frequency (RF) Induction Heating Concept

The RF induction heating concept consists of using commercially available units to supply RF energy to a work coil. A contact is mounted in a non-metallic heat resistant support within the coil so as to inductively-heat the metal contact barrel and thereby melt and flow the solder around the inserted wire conductor. Power is removed from the work coil and the solder is allowed to solidify and cool.

Procedure

This concept was tried as outlined above, using a 5 KW Lepel Model T-2.5-1-KC-AP-B. As with the three prior concepts, a protective band was used to cover the inspection hole.

Results

The solder fillets were inconsistent and dull and frosty in appearance for the same reasons as for concepts 1, 2 and 3. The protective band was not damaged since RF heats only the metal.

Compatibility With Mechanized Concept

The RF induction heating concept, with reservations, could be compatible with a mechanized concept. The main advantages are:

1. Clean - a non-contacting heat source.

The main disadvantages are:

1. Heat cycle is slow (10-15 seconds using 5 KW unit).
2. Mechanics are complicated (due to inherent work coil design limitations for small objects).
3. Difficult to confine heat zone or prevent insulation degradation.
4. Expensive RF equipment.
5. High energy consumption.

Concept No. 3 - The Infrared (IR) Heating Concept

The IR heating concept consists of using commercially available quartz-iodine lamps whose radiant energy outputs are focused onto a contact held in a heat resistant support. The IR causes the solder to melt and flow around the inserted wire conductor, after which the lamps are turned off and the solder is allowed to solidify and cool.

Procedure

This concept was tried using the ellipsoidal reflector lamp assembly on one of the surplus SAFEGUARD coaxial termination machines designed and built by Raychem for Western Electric. The protective band was used as with the prior concepts to cover the inspection hole.

Results

The solder fillets were inconsistent and dull and frosty in appearance for the same reasons as for concepts 1 and 2. The protective band prevented solder leakage but was nearly destroyed by the intense heat.

Compatibility With Mechanized Concept

The IR heating concept is deemed with reservations to be incompatible with a mechanized concept. The main advantages are:

1. Fast (2-3 seconds to melt solder in the contact).
2. Clean - a non-contacting heat source.

The main disadvantages are:

1. Difficult to focus onto desired surface.
2. Difficult to confine; requires platinum shields to prevent degradation of wire insulation.
3. Mechanics are complicated.
4. The inspection hole must be covered.

Concept No. 2 - The Hot Gas Concept

The hot gas concept consists of using a commercially available hot air, flameless torch that is focused onto a contact held in a heat resistant support. The hot gas causes the solder to melt and flow around the inserted wire conductor, after which the hot gas is turned off and the solder is allowed to solidify and cool.

Procedure

This concept was tried as outlined above, using a Henes Model FT-75 flameless torch clamped so as to focus the hot gas stream onto the side of the contact barrel itself and not on the end of the barrel. This was done so as to minimize discoloration of the wire insulation. As with the heated jaw concept (No. 1), a band of shrinkable tubing was used to cover the contact inspection hole. The band was narrower, however, so as to expose as much contact surface as possible to the hot gas stream. RA flux and a premeasured length of solder were inserted into the contact hole, after which a fine Kovar wire (transistor lead) was inserted into the molten solder and jiggled back and forth until all gases and flux appeared to have escaped from beneath the solder. A pre-tinned wire was then inserted into the molten solder in the contact barrel. When the solder fillet appeared to be proper between the end of the contact barrel and the wire conductor strands, the hot gas gun was turned off and the solder was allowed to solidify and cool.

Results

The solder fillets were inconsistent, and for the same reasons as for Concept No. 1. The solder also had a dull and frosty appearance. Since these contacts were allowed to cool without being disturbed, the frosty appearance must have been due to contamination of the solder by gold from the plating inside the contact barrel, and not due to solder movement during solder solidification.

Compatibility with Mechanized Concept

Compared with other methods, the hot gas concept is not compatible with a mechanized concept:

1. Heat cycle is slow (5-6 seconds).
2. Mechanics are complicated (multiple gas nozzles are required that must be in close proximity to contact).
3. The inspection hole must be covered.
4. Wire insulation is subject to degradation.

Concept No. 1 - The Heated Jaw Concept

The heated jaw concept consists of using hot metal jaws with appropriate cutouts shaped to surround and hold the contact. As the heat is applied to the contact, the solder melts and flows around the inserted wire conductor, after which the jaws are removed and the solder is allowed to solidify and cool.

Procedure

This concept was tried by using a 100 watt iron with a tip milled out to accept a contact. Solder leakage from the contact inspection hole was prevented by a band of shrinkable tubing around the contact that shrank when the contact was dropped into the hot iron tip. RA flux and a premeasured length of solder were inserted into the contact hole, after which a fine Kovar wire (transistor lead) was inserted into the molten solder and jiggled back and forth until all gases and flux appeared to have escaped from beneath the solder. A pre-tinned wire was then inserted into the molten solder in the contact barrel. When the solder fillet appeared to be proper between the end of the contact barrel and the wire conductor strands, the soldered assembly was quickly lifted away from the heated jaws and held still until the solder solidified and cooled.

Results

The solder fillets were inconsistent, being highly dependent on the amount of solder picked up by the wire during the prior pre-tinning operation. Furthermore, what appeared to be the correct solder fillet, when molten, shrank to a negative fillet beneath the end of the contact barrel when solid. Results were poorer with un-tinned wire, due to inferior wetting of the wire conductor strands. The solder had a dull, frosty appearance. Subsequent concept studies indicated that the cause was contamination of the solder by gold from the plating inside the contact barrel, and not by moving the joint while still hot as was first suspected.

Compatibility with Mechanized Concept

Compared with other methods, the heated jaw concept is not compatible with a mechanized concept:

1. Heat cycle is slow (5-6 seconds)
2. Mechanics are complicated (the contact must be held motionless until the molten solder has cooled; thus the heated jaws must be moved toward the contacts to heat and then moved away to allow the contact to cool.
3. The inspection hole must be covered to prevent leakage of molten solder.

Program Study

Six different soldering approaches were studied in an attempt to obtain the optimum conceptual process for soldering wire conductors into contacts. Concepts No. 1 through No. 5 utilized conventional crimp-type contacts that were filled with precise amounts of solder, while Concept No. 6 utilized a coaxial contact that was specifically developed for SAFEGUARD ground support cables. The approaches studied were:

1. Heated jaws
2. Hot gas
3. Infrared (IR)
4. Radio frequency (RF) induction
5. Resistance soldering
6. Solder sleeve termination.

Laboratory setups were used to study Concept Nos. 1, 2, 3 and 5; a manual production machine was used for Concept No. 4; and specifically developed SAFEGUARD coaxial contact production termination machines were studied for Concept No. 6.

None of the approaches studied are commercially available for the mechanized soldering of wire conductors to contacts. In addition, there has been no custom equipment located that is compatible with the mechanized concept proposed by this program.

INTRODUCTION

This report will describe the program efforts on the investigation of solder terminations to connectors. A thorough study was made of the methods of soldering contacts to wires and a comparison made to crimp termination. The program investigated the various methods of applying heat to a joint in order to produce an acceptable solder termination.

PHILOSOPHY

To develop a conceptual approach to a soldering process compatible with a mechanized harness fabrication facility, many parameters must be identified and analyzed in order to produce a process and a product that fulfills the requirements while remaining within specification restrictions. Some of these factors are:

- Equipment capability with the total system
- Satisfactory wetting, fillet, etc.
- Cycle time
- Part alignment and concentricity
- Cleaning
- Tinning
- Use of presoldered contacts
- Degradation of insulation

During the course of the program study, many of the methods under consideration were eliminated because of difficulties in these areas.

A STUDY OF SOLDERING CONCEPTS
FOR THE SOLDER TERMINATION
OF WIRES INTO CONTACTS

BY: Earl F. Lish

For

U. S. Army Missile Command
Redstone Arsenal
Richard A. Kotler, Program Director

Supplement Data for
Contract No. DAAH01-74-C-0977

F. E. Tartaglia
Task Leader

Martin Marietta Aerospace
Orlando, Florida

APPENDIX I

A STUDY OF SOLDERING CONCEPTS FOR THE SOLDER

TERMINATION OF WIRES INTO CONTACTS

5.0 REFERENCES

Ref. No.

- 1 OR 13,345 - Application of Automated Manufacturing Process to Methods for Affixing Electrical Connectors to Cables.

First Quarterly Progress Report, October 1974.
- 2 OR 13,345-1 - Application of Automated Manufacturing Process to Methods for Affixing Electrical Connectors to Cables.

Second Quarterly Progress Report, January 1975.
- 3 OR 13,345-2 - Application of Automated Manufacturing Process to Methods for Affixing Electrical Connectors to Cables.

Third Quarterly Progress Report, April 1975.
- 4 OR 13,345-3 - Application of Automated Manufacturing Process to Methods for Affixing Electrical Connectors to Cables.

Fourth Quarterly Progress Report, July 1975.

4.0 TECHNICAL APPROACH

4.5 Program Extension

4.5.3 Conclusions and Recommendations

Fabrication of Sample Harness

The presizing of wires in harness fabrication was verified as a feasible concept and it was recommended that the conceptual design go ahead using this principle.

Study of SAFEGUARD Equipment

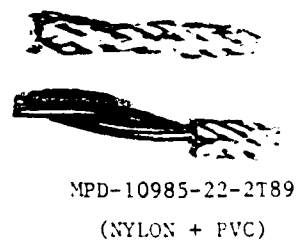
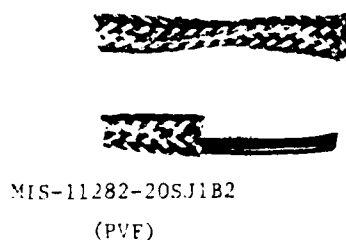
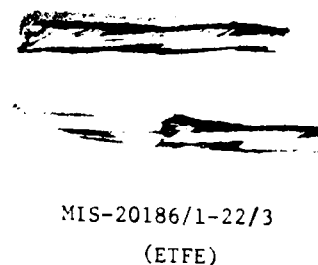
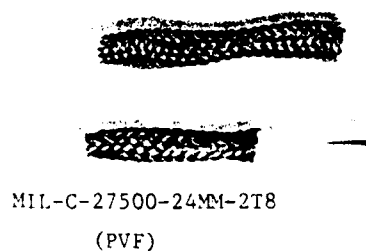
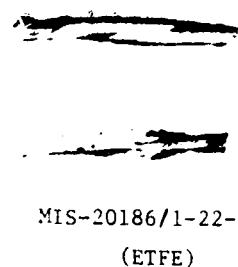
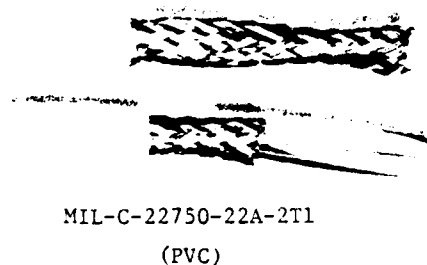
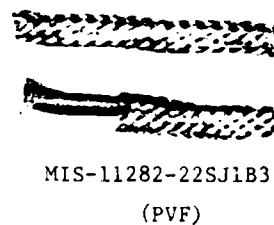
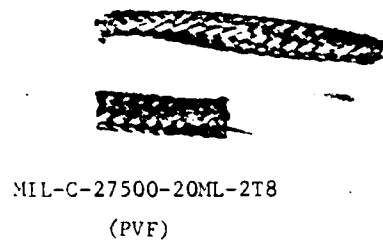
The SAFEGUARD equipment was not generally compatible with the program concept principles. However, the test position showed some promise and should be examined more closely when the test unit is being designed.

Study of Stripping Methods

Both the thermal stripping and the flash stripping processes showed insulation discoloration. Analysis should be made of the stripped wires to determine if any significant degradation occurred at the strip point.

Solder Termination Study

The solder termination process should be examined and closer controls established, based on the conceptual hardware and the sample pieces used to demonstrate feasibility.



Top of pairs = thermal
Bottom of pairs = flash

FIGURE 12. SAMPLES OF STRIPPED WIRE

residue is impossible to remove once the solder sleeve is heated and has shrunk, MIL-S-45743 is not applicable. The controlling documents for solder sleeves are MIL-STD-454D, Req.5, and project peculiar MIS documents such as MIS-20067B.

- 4.0 The wire insulation was charred during solder fillet formation per the IR concept, contrary to para. 4.3.6 which states: The insulation shall not be charred, frayed, split, or pinched through exposing the conductor wire. Slight discoloration of insulation shall not be considered cause for rejection.
- 5.0 The wire insulation shrank during solder fillet formation per both the IR and RF concepts, thereby increasing the insulation clearance excessively since para. 4.3.6 also states: Insulation clearance shall be in accordance with 3.3.3.2.1 (see Figure 38).
- B. Compatibility With Mechanical Concept
 - 1.0 The following concepts are not compatible with a mechanized concept:
 - No. 1 Heated Jaw - Slow (5-6 seconds) heat cycle; complicated mechanics.
 - No. 2 Hot Gas - Slow (5-6 seconds) heat cycle; complicated mechanics(tends to degrade wire insulation).
 - No. 3 IR - Difficult to focus or confine; complicated mechanics (tends to degrade wire insulation).
 - No. 4 RF - Slow (10-15 seconds) heat cycle; complicated mechanics; difficult to confine (tends to overheat wire and thus degrade insulation).
 - No. 6 Solder Sleeve - Very slow (20-24 seconds) heat cycle; complicated mechanics; difficult to confine (tends to degrade wire insulation).
 - 2.0 The following concept is the only one investigated that is compatible with a mechanized concept:
 - No. 5 Resistance Soldering - Fast (1-2 second heat cycle; 2-4 second cool cycle; 2-3 second flux removal cycle); simple mechanics; automatic coverage of inspection hole.

Recommendations

It is recommended that the resistance soldering method (Concept No. 5) be selected as the prime candidate for the mechanized concept because of its compatibility with that concept, e.g.:

1. Resistance soldering is fast (5-9 seconds including flux removal).
2. The mechanisms would be relatively simple.
3. The inspection hole would be automatically covered.

In comparing soldering with crimp methods of terminating wire conductors to contacts, it is further recommended that the crimp method be selected and used wherever possible in the mechanized concept for the following reasons:

1. Crimp equipment is already available that will automatically affix contacts to wire conductors.
2. The available crimp equipment can become part of the proposed mechanized concept with a minimum amount of adaption required.
3. Soldering equipment is not available; a machine must be designed, developed and fabricated for the mechanized soldering of wire conductors into contacts.
4. The need for pre-tinned wire will require radical modification of existing wire prep equipment or will require a separate unit.
5. The need for solder-filled contacts will require the design, development and fabrication of a separate machine by either the contact manufacturer or as part of the mechanization facility.

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